ATSC 212

FORTRAN - part 1

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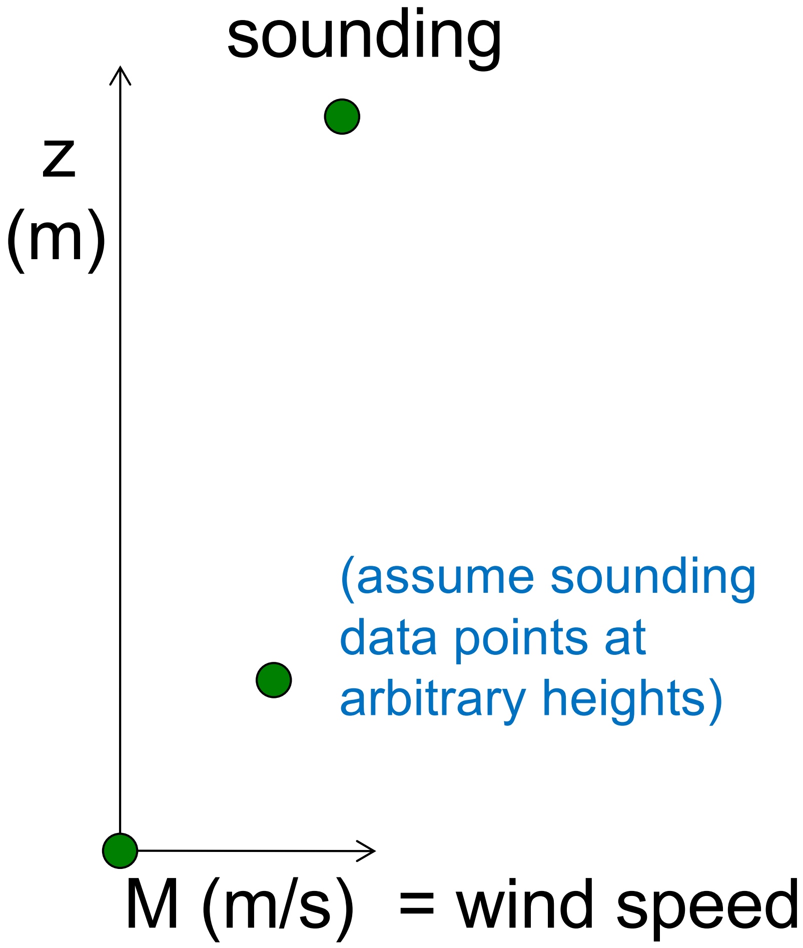
Goals for Today’s Lab

- Intro to evolution of fortran
- Write & run a simple fortran program -- the start of a larger program to calculate wind power.
- Learn about compiler error messages, and tips for debugging.
- Get experience with fortran syntax and control structures.
- Learn & use version control.
- Learn & use top-down programming.

Discussion on blackboard of plan of attack for the wind power calculation = $0.5\cdot\rho\cdot A\cdot M^3$

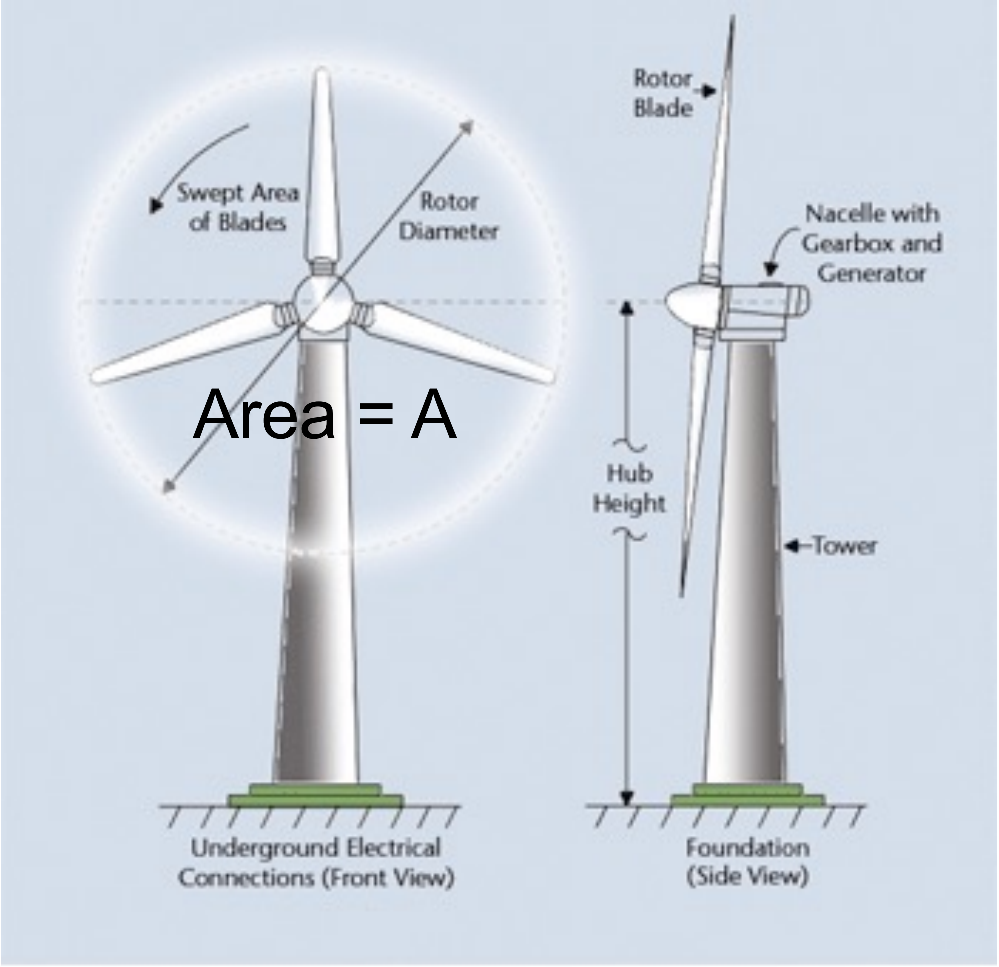


sounding

z (m)

(assume sounding data points at arbitrary heights)

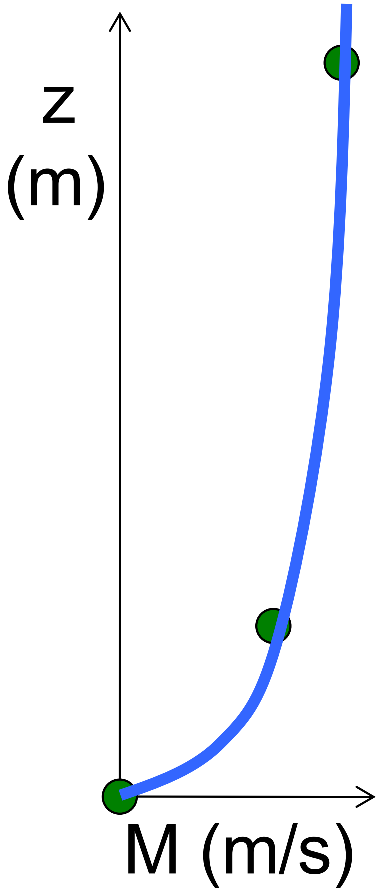
M (m/s) = wind speed

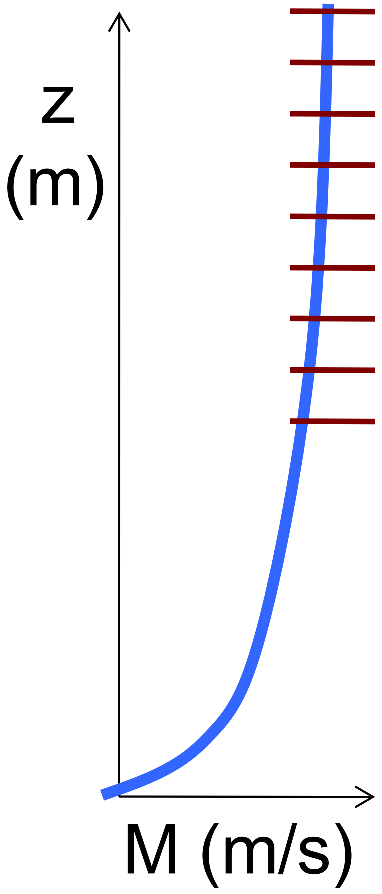


Area = A

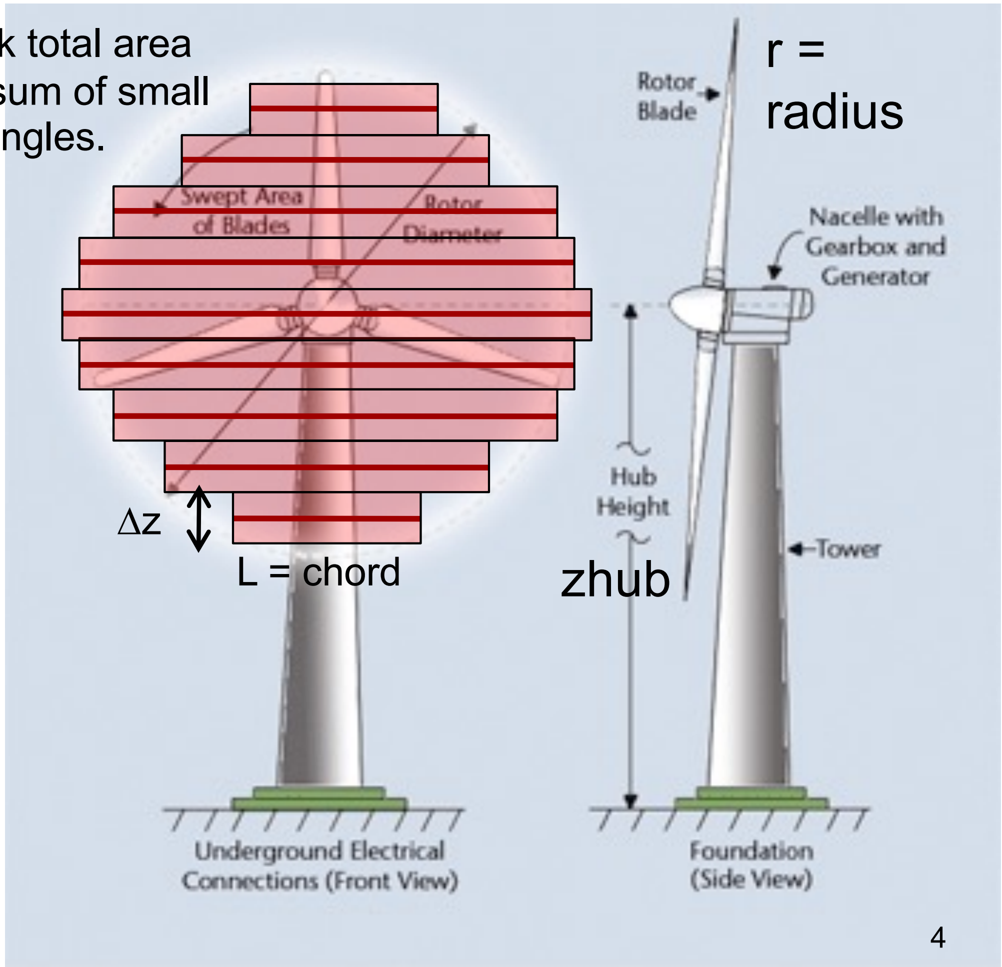
Drawing of the rotor and blades of a wind turbine, courtesy of ESN

Discussion on blackboard of plan of attack for the wind power calculation = $0.5 \cdot \rho \cdot A \cdot M^3$





Break total area into sum of small rectangles.



Δz

L = chord

r = radius

zhub

Drawing of the rotor and blades of a wind turbine, courtesy of ESN

Useful Formulas:

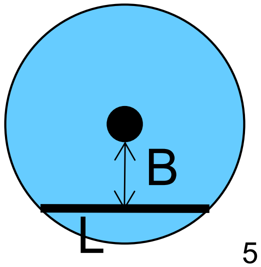
Power (W) = $0.5 \cdot \rho_{air}(kg/m^3) \cdot A(m^2) \cdot [M(m/s)]^3$

where A is disk area swept out by the turbine blades
M is wind speed
ρ_{air} is air density.

$\rho_{air} = \rho_o \cdot e^{-z/H}$, where this z is height above sea level, and

where $\rho_o = 1.225\ kg/m^3$, and scale height H = 8550 m

The length L of a circle's chord that is distance B from the circle center is: $L = 2 \cdot [r^2 - B^2]^{1/2}$ where r = circle radius, and $B = z_{hub}(agl) - z(agl)$. (agl = above ground level).



FORTRAN = FORmula TRANslation

- Designed to solve scientific equations on high performance computers.
- Is under active development. https://fortran-lang.org
- Is natively parallel. So it can run fast.
- Was the first high-level language (HLL). Reads like English.
- Is independent of the particular processor (i.e., is portable). Differs from Assembly Lang.
- Is an “imperative” language. Do this. Then do that.
- Is a “procedural” language. Breaks tasks into subroutines & functions.
- Is an “array-oriented” language. Create arrays as you would write on paper.
- Is an “object-oriented” language. More intuitive than “C” objects.
- A compiler reads the standard FORTRAN code (ascii text, written by humans) as input, and produces specialized machine code (binary) as output. (Each processor needs a different compiler.)
- We then “run” or “execute” the compiled code.
- Modern compilers “optimize” the code. Make it run faster.

FORTRAN evolution

(see timeline of programming languages)

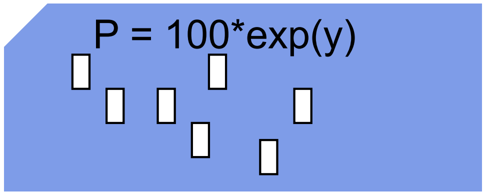
- FORTRAN I (released in 1957 by IBM)
- FORTRAN II (1958, separate compile & link)
- FORTRAN IV (1961. Machine independent.)
- FORTRAN 66 (First ASA standardized version.)
- FORTRAN 77 (ASA standardized in 1977)
- FORTRAN 90 (a major upgrade. Modern. Includes array math.
  Adopted as standard by ANSI and ISO / IEC.)
- FORTRAN 95 (a minor change from F90)

- FORTRAN 2003 (a moderate upgrade, with object prog.) ★
- FORTRAN 2008 / 2010 (minor changes.)
- FORTRAN 2018 (significant upgrade. IEEE floating-point std.)
- FORTRAN 2023 (minor bug fixes)

(see a nice summary in Wikipedia)

The old days…thru F77

- Input was via computer cards.
- Output was to a line printer.
- Batch jobs. Not interactive.
- Programmers served the computer, not the computer serving the programmers.
- Column alignment of code



The new days… F90 & newer.

FORTRAN Tutorial

- An excellent FORTRAN tutorial was created by Stephen Brooks, Univ. of St. Andrews, Scotland. (Copies of his tutorials are presented on our web page.)
- Google can find other good turorials, eg: https://pages.mtu.edu/~shene/COURSES/cs201/NOTES/fortran.html
- See the Resources link on our course web page for access to a full FORTRAN language manual.
- Also see Wikipedia "Fortran language features"

Steps in FORTRAN programming

- Design algorithms and program flow (e.g., using a flow chart).
- Write/Edit the FORTRAN code (which is just an ascii text file) on a text editor, & save as a “source” code file.
- Compile the source code into binary “object” files, by running a FORTRAN compiler program.
- Link the compiled object files to other compiled subroutines or libraries, if needed, to create an “executable” binary file. (“Make" files are scripts that tell the computer which compiled files and libraries to combine and link together.)
- Run the resulting executable.

Editing: Program Editors

Some ascii text editors use GUI interface (g) with mouse.

"Program editors" are ascii text editors that can color-code (cc) statements for different programming languages.

Examples of editors for different computer systems:

- MacOSX: TextEdit(g), BBEdit(g,cc)
- PC Windows: NotePad(g) [DON'T use WordPad]
- Linux: VI(cc), Emacs(g,cc) [Old school.]

Some commercial software provides a full "programmers environment" (editors, compilers, debuggers, profilers)

- Visual Studio (MicroSoft, for Windows machines)
- CodeWarrior (for many systems)
- Absoft (for Mac, Windows, and linux)

Preliminary set-up

Assuming that you have either installed the gfortran compiler on your own computer, or you have remote access to a server that has gfortran, then let's get set up for the tutorial.

1) Open a (command line) terminal window.
2) Create a directory (a folder) called "`fortran`". Here is how: (a) First, log into the computer you will be using. (b) If using a terminal window, first use the "`cd`" command to move to an existing directory where you want to put "`fortran`" , and then use "`mkdir fortran`" to make the new directory. Or directly on your Mac or windows, use the normal graphical user interface (GUI) to create a new folder called "`fortran`" . (c) On your terminal window, use "`cd`" to navigate to your new fortran folder.
3) Open your user-friendly program editor. Or be prepared to use vi in your terminal window to write your fortran code.
4) Copy two sounding-data files into your fortran folder: `darwin.txt` and `porthardy.txt` . You can find them at:
https://www.eoas.ubc.ca/courses/atsc212/labs/fortran-1/inputdata/darwin.txt
https://www.eoas.ubc.ca/courses/atsc212/labs/fortran-1/inputdata/porthardy.txt
(Hint, in linux/bash, use the "`wget`" command from inside your fortran folder. But in MacOX/zsh, use the "`curl –O`" command.) capital letter O .

Editing: An example

First, write the “source” code. Follow along with the instructor.
Open your editor to do this. This will be version 01 of our program.

```
! Estimate wind power
program windpowermain
  write(*,*) "Welcome to Wind Power"  !welcome user
end program windpowermain
```

Save the source-code file to your fortran folder, using suffix “.f95”. For example, for wind_power-version-01, we could name our file:

For example: `wp01.f95`

Notes:

Comments start with an exclamation point.

[Good programming practice to document WHILE you write your code.]

FORTRAN is case insensitive. X and x are the same variable.

Hit the “Return” or “Enter” key at the end of each line. No special character is used at the end of each line.

Each line can be up to 132 characters long.

If you need a longer line, end the first line with &
& and start the continuation line also with the ampersand.

Compiling: Compiler Programs

- FORTRAN compilers exist for almost all computers, including desktop PCs and Macs.
- Some are optimized for HPCs, and have VERY nice editing and debugging environments. Some are expensive; some are free.
  [Tim Chui says: For Intel processors, use Intel oneAPI (free):
  https://www.intel.com/content/www/us/en/developer/tools/oneapi/toolkits.html#gs.bt9mjf
  For most other processors (including AMD) + "easy" GPU programming, use NVIDIA HPC SDK (also free):
  https://developer.nvidia.com/hpc-sdk]
- Some free FORTRAN compilers that run on most platforms (linux, Mac, PC) are available. These might not be the fastest, but are good for general-purpose uses and for learning:
  - `https://gcc.gnu.org/wiki/GFortran`

    produced by the GNU organization.
- We will use gfortran in this course.
  Use this link to install gfortran: https://fortran-lang.org/learn/os_setup/install_gfortran/

Compiling & Running under linux

Example. You should follow along, in your terminal window.
First navigate (use the cd command) to get to your "fortran" directory/folder.

```
➢ gfortran wp01.f95 -o runwp01  #invoke the compiler

➢ ./runwp01                   #run the executable
Welcome to Wind Power         #this is the output

➢                             #the next linux prompt
```

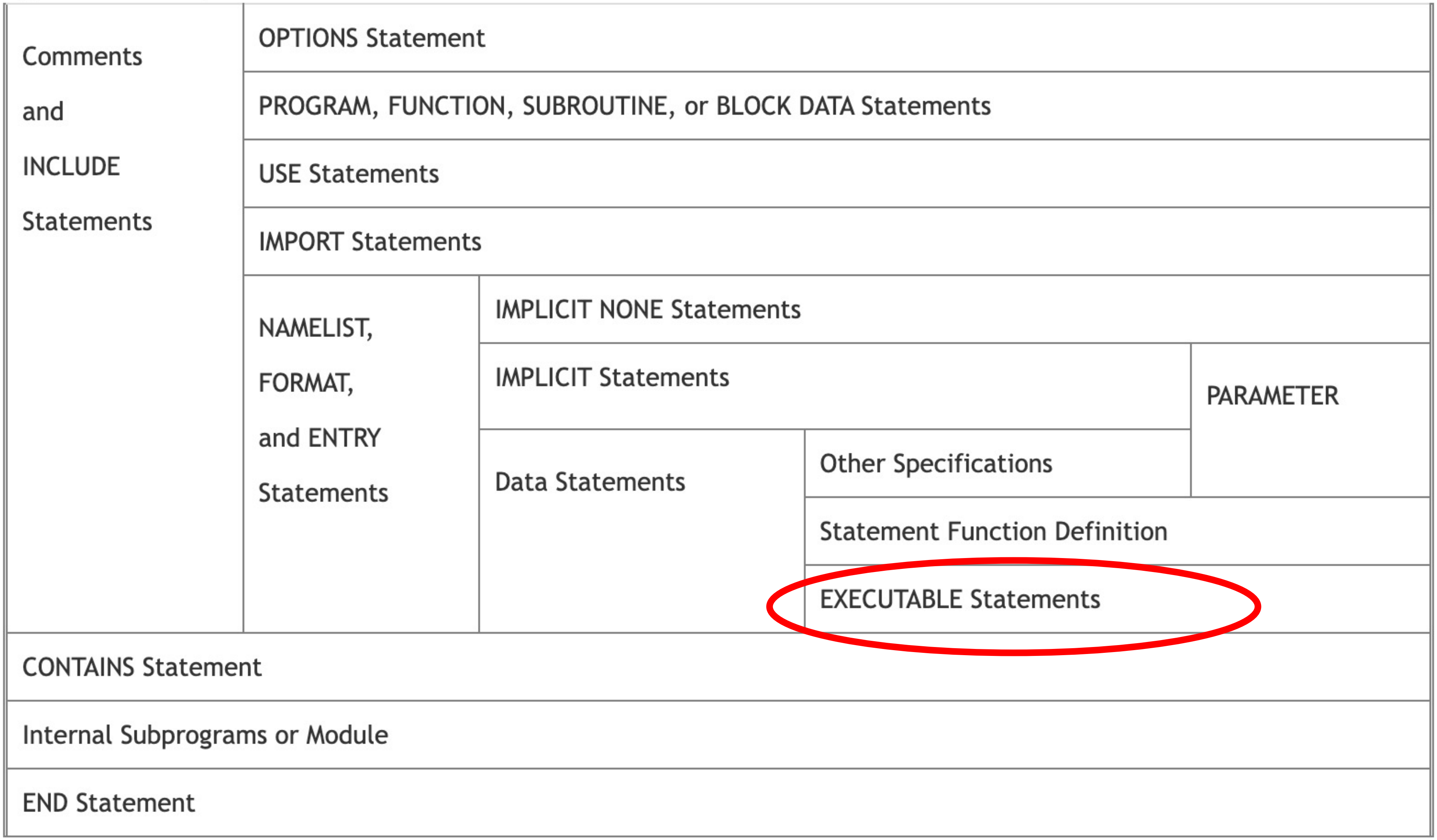
Notes:

"gfortran" is the name of the fortran 95 compiler.
It takes the text file "wp01.f95" as input.
The "-o" option tells the compiler that you will provide a name for the output file.
I have named the output executable file "runwp01".
(Although not needed, some programmers like to name executable files with suffix ".exe". Such as "runwp01.exe")

Some Elements of FORTRAN

- Variables (including array variables)
- Operators (assignment, math, logical)
- Conditionals
- Loops
- Functions & subroutines (& built-in functions)
- I/O: input from keyboard & output to screen
- File Handling

Order of Statements



<table>
<tr><td rowspan="9">Comments
and
INCLUDE
Statements</td><td colspan="4">OPTIONS Statement</td></tr>
<tr><td colspan="4">PROGRAM, FUNCTION, SUBROUTINE, or BLOCK DATA Statements</td></tr>
<tr><td colspan="4">USE Statements</td></tr>
<tr><td colspan="4">IMPORT Statements</td></tr>
<tr><td rowspan="5">NAMELIST,
FORMAT,
and ENTRY
Statements</td><td colspan="3">IMPLICIT NONE Statements</td></tr>
<tr><td colspan="2">IMPLICIT Statements</td><td rowspan="2">PARAMETER</td></tr>
<tr><td rowspan="3">Data Statements</td><td>Other Specifications</td></tr>
<tr><td colspan="2">Statement Function Definition</td></tr>
<tr><td colspan="2">EXECUTABLE Statements</td></tr>
<tr><td colspan="5">CONTAINS Statement</td></tr>
<tr><td colspan="5">Internal Subprograms or Module</td></tr>
<tr><td colspan="5">END Statement</td></tr>
</table>

Source: PGI Fortran Reference Manual, downloaded Jul 2024from https://docs.nvidia.com/hpc-sdk/pgi-compilers/19.10/x86/fortran-ref-guide/index.htm

Variables: Type Declarations

Although FORTRAN does not require that variables be declared before you use them, it is VERY good practice to do so. To enforce such “strong typing” of variables, you should always declare “`implicit none`” first.

Reals are floating point numbers (with a decimal **3.14** and optionally with as scientific notation **8.99E-6** which means 8.99 x 10^{-6} .

Integers are whole numbers.

Characters are strings of ascii characters of length 0 or more, in quotes. **“line”**

Logicals are boolean variables such as **.false.** or **.true.**

```
implicit none       !impose strong typing
real :: e           !vapour pressure (kPa)
real :: p = 101.325 !total pressure (kPa), initialized.
real, parameter :: epsilon = 0.622   !constant. Can’t change.
integer :: nlevel                !number of sounding levels
character (len=80) :: inputline !string of input characters
logical :: done = .false.       !a flag indicating if done
```

Try it – Type declarations

First, make a copy of your old program and give it a new version name. Eg:

- in linux, use “`cp wp01.f95 wp02.f95`”
- on a Mac, open “`wp01.f95`” and do "save as" with name "`wp02.f95`”, or in a finder window, use command-D to duplicate the old file; then rename it.

Version Control is Good Programming Practice.

Next, add code as shown in black (follow along with instructor), and save.

```
! Estimate wind power

!========= main program =============
program windpowermain

! declare variables
  implicit none                     !enforce strong typing
  real :: power = 0.0               !power (W) outout from turbine

!set up
  write(*,*) "Welcome to Wind Power"  !welcome user

!save results
  write(*,*) "power = ", power        !display result

end program windpowermain
```

Try it.   Compile and run.

```
➢ gfortran wp02.f95 -o runwp02  #invoke the compiler
➢ ./runwp02                     #run the executable
Welcome to Wind Power           #this is output
power =    0.000000             #this is more output
➢                               #the next linux prompt
```

Good.
Next, lets look at error messages and debugging.

Try it – Finding & fixing errors

First, do "save as" or cp with name "wp03.f95", to create a new version.

Next, change the code as shown, save, compile, & execute.

```
! Estimate wind power

!========= main program =============
program windpowermain

! declare variables
  implicit none                   !enforce strong typing
  real :: power = 0.0             !power (W) outout from turbine

!set up
  write(*,a) "Welcome to Wind Power"    !welcome user

!save results
  write(*,*) "power = ", power   !display result

end program windpowermain
```

Try it – Error Messages

Your output might look like:

```
wp03.f95:11

  write(*,a) "Welcome to Wind Power" !welcome user
          1
Error: Symbol 'a' at (1) has no IMPLICIT type
```

It tells you:

1) which program had the error: which line of code (line 11) had the error.

2) it displays a copy of the offending line, and then under it uses "1" to point to the error.

3) it explains the reason for the error.

Try it – Debugging

Next fix that first error. Then make a different error by forgetting to write the ending set of quotes. Change the code as shown, save, compile, & execute.

```
! Estimate wind power

!========= main program =============
program windpowermain

! declare variables
  implicit none                  !enforce strong typing
  real :: power = 0.0            !power (W) outout from turbine

!set up
  write(*,*) "Welcome to Wind Power     !welcome user

!save results
  write(*,*) "power = ", power   !display result

end program windpowermain
```

Try it – More Error Messages

Your output might look like:

```
wp03.f95:11

  write(*,*) "Welcome to Wind Power !welcome user
            1
Error: Unterminated character constant beginning at (1)
```

It tells you:

1) which program had the error: which line of code (line 11) had the error.

2) it displays a copy of the offending line, and then under it uses "1" to point to start of the section that had the error.

3) it explains the reason for the error.

Note: These errors can be caught in editors with colored highlighting of syntax.

Version Control – good programming practice

One of the reasons for saving previous working versions of the code, is that you can always revert back to a previous good version if you screwed up the new version so bad that you can't fix it easily.

Also, by making only small changes to the new version, you can more easily isolate the likely places where the error could be. This speeds debugging.

Lets do it. Just delete the version 3 (`wp03.f95`) from your editor, and open version 2 (`wp02.f95`). Then immediately save it as a new version 3 (`wp03.f95`).

To encourage this, the markers for this course will need to see ALL versions in your directory, for you to earn full marks.

Variables: Arrays

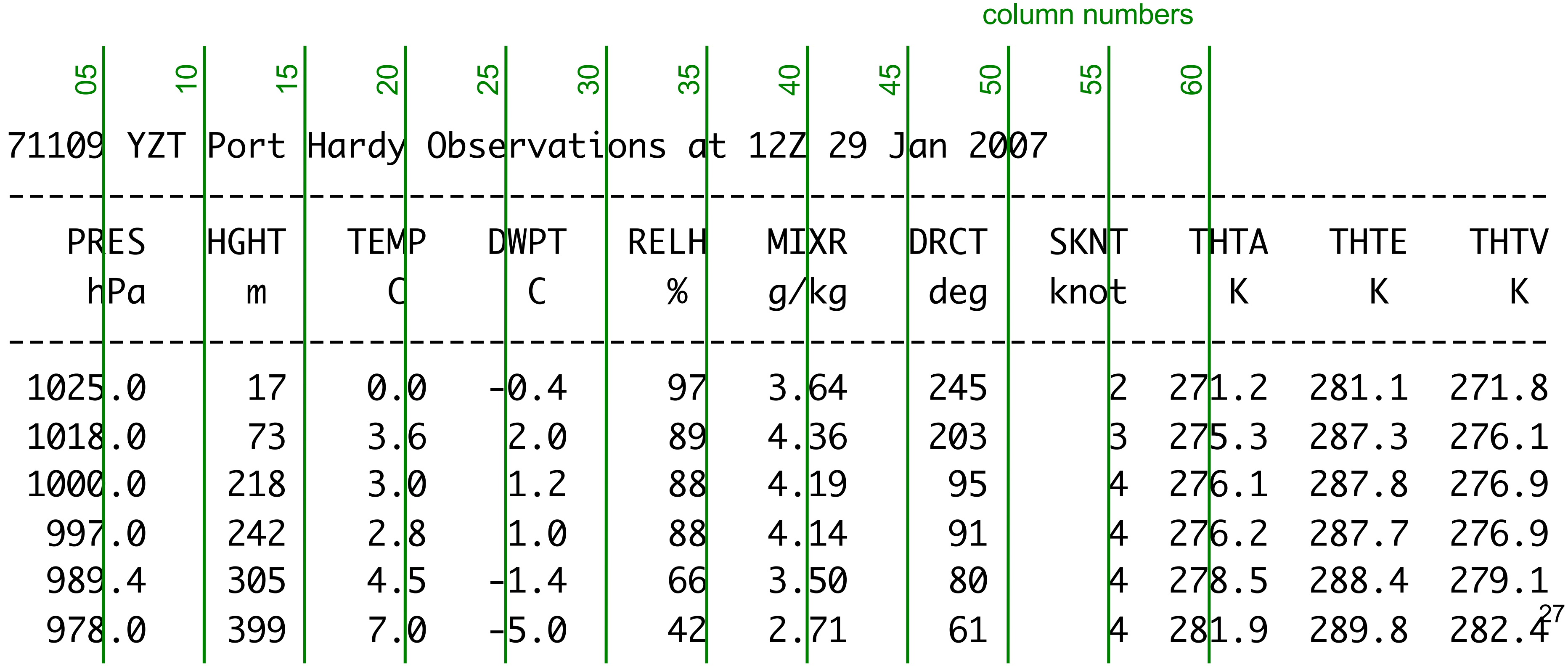
```
!Here is how you can declare 1-D array variables:
real, dimension(16) :: temperature
integer, dimension(10) :: digits
character (len=100), dimension(120) :: poem

!Or, for a 2-D array:
real, dimension(120,2) :: sounding

!Then, you can reference any array element in a 1-D array by:
integer :: i, d
real :: T
character (len=100) :: line
i = 3
T = temperature(i)
d = digits(i)
line = poem(i)
```

Wind Energy

Your program will read the wind data from a meteorological sounding text file as shown below. Thus, we can anticipate that we will need to have arrays of heights, wind directions, wind speeds, and lines in the sounding.

To see these sounding data, type “`cat porthardy.txt`” .

(Thanks to the Univ. of Wyoming for the sounding data.)



```
71109 YZT Port Hardy Observations at 12Z 29 Jan 2007
-----------------------------------------------------------------------------
   PRES   HGHT   TEMP   DWPT   RELH   MIXR   DRCT   SKNT   THTA   THTE   THTV
    hPa     m      C      C      %    g/kg    deg   knot     K      K      K
-----------------------------------------------------------------------------
 1025.0     17    0.0   -0.4     97   3.64    245      2  271.2  281.1  271.8
 1018.0     73    3.6    2.0     89   4.36    203      3  275.3  287.3  276.1
 1000.0    218    3.0    1.2     88   4.19     95      4  276.1  287.8  276.9
  997.0    242    2.8    1.0     88   4.14     91      4  276.2  287.7  276.9
  989.4    305    4.5   -1.4     66   3.50     80      4  278.5  288.4  279.1
  978.0    399    7.0   -5.0     42   2.71     61      4  281.9  289.8  282.4
```

Try it ...

Add the following type declarations to the "declare variables" part of your wp03.f95 code, save, compile, and run.

```
integer, parameter :: maxlines = 120   !max sounding lines that can be captured
real, dimension(maxlines) :: zmsl       !array of heights MSL (m)
real, dimension(maxlines) :: speed      !array of wind speed (knots)
character (len=100), dimension(maxlines) :: sounding   !holds the whole sounding
```

Your output from ./runwp03 should still say:

```
Welcome to Wind Power
 power =     0.000000
```

Operators

Operators allow you to perform actions on variables.

Assignment: **=**

Mathematical: **+ , - , * , / , **** (unary **+** , **-**)

Logical:	**==**	or	**.eq.**
	/=	or	**.ne.**
	>	or	**.gt.**
	>=	or	**.ge.**
	<	or	**.lt.**
	<=	or	**.le.**
	.and.		
	.or.		
	.not.	(unary)	
	.eqv.	(logically equivalent...)	
	.neqv.	... or not)	

SUBROUTINES

("helper" functions)

```
program somemath
  implicit none             !Enforce strong typing
  real :: x,y,f,p     !Declare variables
  . . .                    !prompt user to enter x and y
  call factorial(x,f)     !find the factorial of x
  call power(x,y,p)         !find x to power y
  . . .                    !display results on screen
end program somemath


subroutine factorial(x,f)
  real, intent(in) :: x      !the input variable
  real, intent(out) :: f = 1.0 !initialize factorial
  . . . !calculate f as x factorial
end subroutine factorial   !returns factorial in f
```

Try it ...

First, Save As "wp04.f95" to create a new version. As an example of "top-down" good programming practice, add the following subroutine calls to your main program. Save.

```
!set up
  call welcome
  call getturbinespecs
  call getsounding

!compute wind power
  call findpower

!save results
  call saveresults
```

Try it ...

Next, add subroutine "stubs" that don't do anything except announce that they've been called (to help you debug the program).   For example:

```
 !=======================================
subroutine welcome
  implicit none        !enforce strong typing
  write(*,*)
  write(*,*) "Welcome to Wind Power"
end subroutine welcome

!=======================================
subroutine getturbinespecs
  implicit none        !enforce strong typing
  write(*,*)
  write(*,*) "getturbinespecs: Get specs of the wind turbine."
end subroutine getturbinespecs
```

You can write the other stubs. Then save into wp04.f95, compile, run, fix, and save again.

Try it...

Your output from runwp04 should say:

```
Welcome to Wind Power

getturbinespecs: Get specifications of the wind turbine.

getsounding:  Get the file holding the input sounding

findpower:  Calculate the wind power.

saveresults:  Write to disk and screen the wind power.

power =    0.000000
```

FUNCTIONS

`!Will be discussed next week.`

READ from keyboard and WRITE to screen

```
READ (*,*) variable1, variable2, etc.

WRITE (*,*) variable3, variable4, etc.
```

```
!The first * in the read/write statement
  defaults to the standard input (keyboard) or
  output (screen).  The second * specifies
  “list directed”, unformatted, reads and
  writes.
```

WRITE (more details)

In a write statement, the arguments in the parentheses are:

```
 write (unit number, format) stuff, to, be, written
```

Some examples:

```
   write (*,*) “Wind speed (m/s)= “, M, “  Temp(K)= “, T
!      where * unit number = default = computer screen,
!      and * format = list directed (format is based on
!      the type declarations of the stuff to be written)

 write(*,”(F8.2)”) T
!      Writes a real number to the screen, formatted to print
!      into 8 columns, with 2 digits right of the decimal point.
!       Example: bb273.15  where “b” is a blank space

 write(1,”(a)”) “Hello world”
!      Which writes to a previously-opened file (unit 1),
!      in an alphanumeric (character string) format.
!      File Handling will be explained next week in class.
```

Useful Code Segment for Prompting User to Enter Input

```
character (len=50) :: name
…
…
write(*,”(a)”,advance=“no”) “Type in your name: ”
read(*,*) name
```

```
!This code segment prompts the user to type in something,
!and allows the user to respond by typing on the same line.
!
!The extra advance=“no” specification in the write statement
!prevents the automatic line-feed from happening. It applies
!only to the one write statement in which it is specified.
```

Try it ...

First, Save As "wp05.f95".
Modify subroutine getturbinespecs to prompt the user for the hub height "zhub" and turbine radius "r".

After reading "zhub" and "r", echo (write) those value to the screen (to keep the user happy by confirming the values).

You can either start on your own, or follow along as I write the code.

Hint: Don't forget to declare the new variables in this subroutine before you use them.

Save, compile, debug, run, save.

Try it ...

First, Save As "`wp06.f95`".
Modify subroutine **`getsounding`** to prompt the user to enter the name "`soundingfilename`" of the file holding the sounding.
Also, echo (write) the filename to the screen.

You start on your own, and I will follow along later.

Hint: Don't forget to declare any new variables in this subroutine before you use it.

Save, compile, debug, run, save.

Read from a file (on disk, etc.)

```
INTEGER :: ero,err

OPEN(1,FILE=“filename”, STATUS=“old”, ACTION="read", IOSTAT=ero)
IF (ero .NE. 0) STOP “Can’t open file.”

READ(1,*, IOSTAT=err) variable1, variable2, etc.
IF (err .NE. 0) blahblah   !e.g., EXIT a loop

CLOSE(1)

!(ero=0 if successful, positive if failure).
!   In the OPEN statement, instead of a character string
!   “filename”, you can have a character variable there,
!   which holds the file name.
!(err=0 if successful, -1 if end of file, -2 end of record,
!    positive if failure)
!  For example:
   integer :: ero
   character (len = 30) :: studentroster
   …
   studentroster = “ubc_atsc212_classlist.txt”
   open(1,file=studentroster,status=“old”, action="read", iostat=ero)
   if (ero .ne. 0) stop “Can’t open file.”
```

More File Commands & Info

For the OPEN statement:

ACTION can be "read" or "write". (If the ACTION word is missing, than both read & write is assumed.) Good programming practice: for input files, specify "read" only, to avoid accidently overwriting any important info.

STATUS can be "old", "new", "replace", "scratch", or "unknown". Use old for input files, and replace for output files.

More file commands:

```
WRITE(1,*) "blah"   !for writing to a disk file that you had
                          previously opened as unit 1.

REWIND(1)           !move to beginning of the file that you
                          had previously opened as unit 1.

BACKSPACE(1)        !move back one line in the file that you
                          had previously opened as unit 1.
```

Try it ...

First, Save As "`wp07.f95`".
Modify subroutine **`getsounding`** to open the old file that the user specified, then write to the screen the value of the error flag (don't do the "if" test yet), and finally close the file.

You start on your own, and I will follow along later.

Hint: Don't forget to declare any new variables in this subroutine before you use it. (such as the error flag variable, which is an integer)

Save, compile, debug, run, save.

Hint: If your program can't open the file, be sure that the file (such as darwin.txt) is in the same folder as your program, and don't forget to type the .txt suffix as part of the file name the user types in.

Control Structures: CONDITIONALS

```
Version 1:
  if (logical expression) blah

Version 2:
  if (logical expression) then
     blah
     blah                        !this is a “block” of statements
     blah
  end if

  Examples:

  if (T < 273.) write(*,*) “It’s cold outside.”

  if (i == 5) then
       T = temperature(i) + 273.15    !temperature in K
       E = sigma * (T**4)             !Stefan Boltzmann
       write(*,*) E                   !output to screen
  endif
```

More Conditionals

The IF THEN ELSE statement. The ELSE IF is optional:

```
if (logical expression) then
   blah
   blah
else if (different logical expr) then
   blah
   blah
else if (different logical expr) then
   blah
   blah
else
   blah
   blah
end if
```

Example:

```
if (T<0.) then
  write(*,*) “It is cold.”
elseif (T>40.) then
  write(*,*) “It is warm.”
else
  write(*,*) “It is mild.”
endif
```

Try it ...

First, Save As "wp08.f95".

Modify subroutine **getsounding** to check the file-opening error flag after trying to open the file, and if OK than write to the screen that the file successfully opened. If not OK, then write to the screen about this failure, offer a hint on what to do next time, and stop the execution.

You can follow along as I code it.
Save, compile, debug, run, save.

```
if (ero .ne. 0) then !can't open the file
  write(*,*) "  Sorry.  Can't find the file: ", soundingfilename
  write(*,*) "   Don't forget to add a suffix .txt if needed."
  stop "Bye."
else                        !successfully opened the file
  write(*,*) "  Good.  Successfully opened file: ", soundingfilename
  write(*,*)
endif
```

Try it ...

First, Save As "wp09.f95".

Modify subroutine **getturbinespecs** to check that the turbine radius is less than the hub height, because if the turbine blade is too long, then it will hit the ground. [Good programming practice to check for unphysical or unreasonable values.] If r is greater than or equal to zhub, then tell what the problem is to the user, and allow the user to enter a new radius r.

You can code this on your own, and I will follow later. Save, compile, debug, run, save.

...and More Conditionals

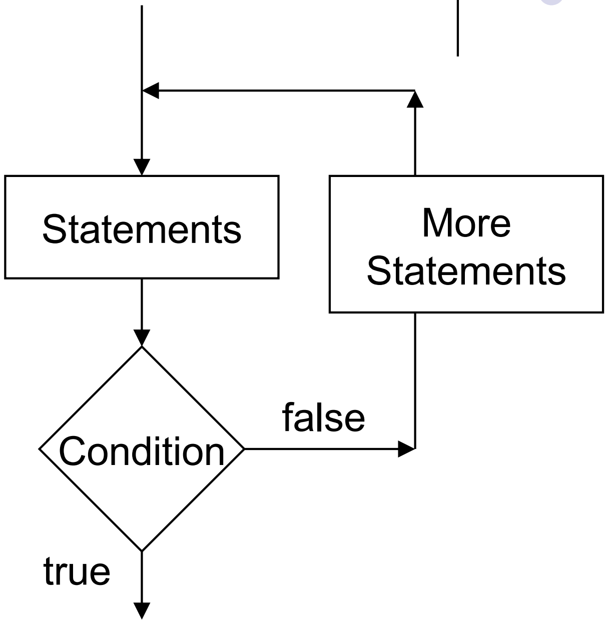
An example of the CASE statement:

```
integer :: T            !temperature (° C)

select case (T)
case (:-1)
  blah                  !for T ≤  -1
case (0)
  blah                  !for T = 0
case (1:20)
  blah                  !for 1 ≤ T ≤ 20
case (25, 32, 47)
  blah                  !for any of the listed T
case default
  blah                  !for all other T
end select
```

Control Structures: Loops

Loops allow us to take repeated actions untill a condition is met.

```
do                !This is a “while” loop
   blah
   blah
   if (logical expression) exit
   more blah
   more blah
end do
```



Example:

```
rh = 80.          !Initialize the relative humidity (%)
do                !Repeat the following statement block
   rh = rh - 25.  !Decrement the relative humidity
   if (rh<=0) exit !Stop repeating if humidity is invalid
    y = x / rh    !Perform some calculation
enddo
```

Try it ...

First, Save As "wp10.f95".

Modify subroutine **getsounding** to read each line of the sounding file, and display the line to the screen as it reads it.

Hint: read each line as a character string called "line".

You can follow along as I code it. Save, compile, debug, run, save.

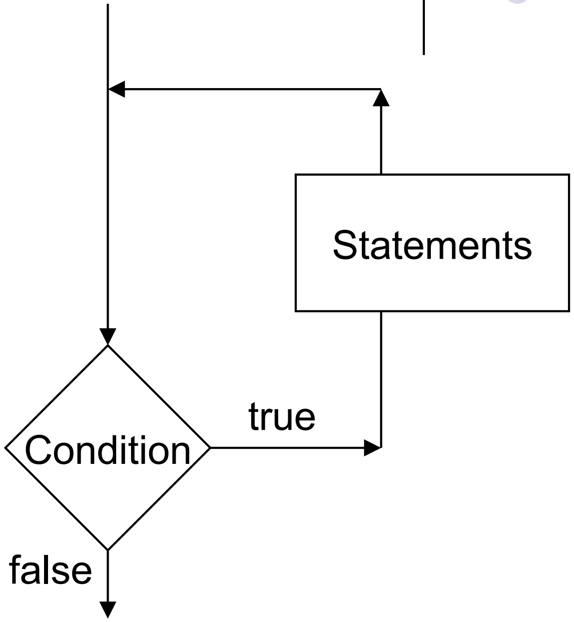
```
character (len=100) :: line        !one line in the sounding file
integer :: err                     !error flag for reading a file

. . .

write(*,*) "======================================="
do                                 !read all lines in the file
  read(1,"(a)", iostat=err) line   !try to read a line
  if ( err .ne. 0  )  exit         !couldn't read the line
  write(*,"(a)") trim(line)        !echo the line that was read
enddo
write(*,*) "======================================="
write(*,*)
```

Note: the "trim" function removes any trailing blanks from the string.

Control Structures: more Loops

Loops allow us to take repeated actions till a condition is met.

```
!This is a "do while" loop
do while (logical expression)
   blah
   blah
end do
```



Example:

```
rh = 80.                !Initialize the relative humidity (%)
do while (rh >= 0)!Repeat the following statement block
   rh = rh - 25.        !Decrement the relative humidity
   y = x / rh           !Perform some calculation
enddo
```

Try it ...

First, Save As "wp11.f95".

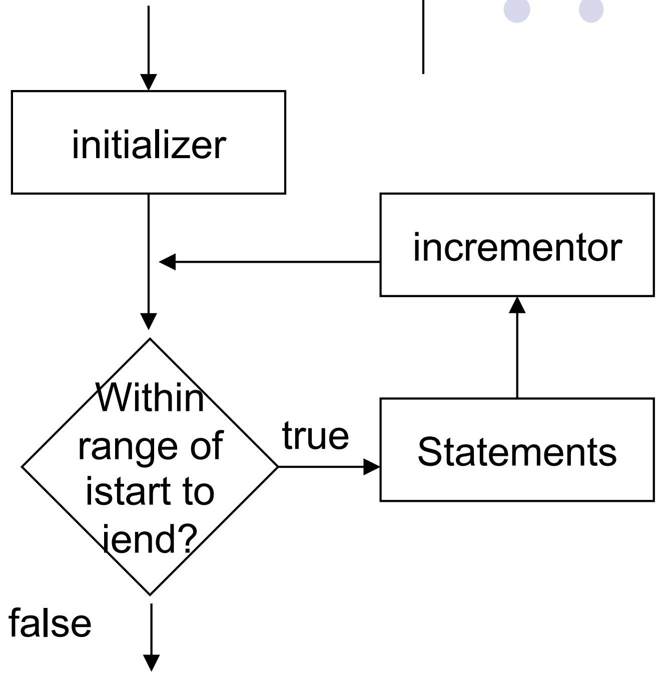
Modify subroutine getturbinespecs to replace the r < zhub conditional statements with a do while loop that allows the user to keep entering r values until a good r value is finally entered.

You can code it. I will follow along later.
Save, compile, debug, run, save.

...and More Loops: the "counting do" loop

For repeated calculations where some index or value increases or decreases with uniform increments:

```
!(if increment is missing, 1 is assumed)

do index = istart, iend, increment
   blah
   blah
   blah
   blah
end do
```



```
Example:
jend = 25              !number of grid points across BC
do j=1,jend,2          !for every second grid point
   M = wind(j)         !extract the wind speed from the array
   accumDrag = accumDrag + CD*(M**2)   !accumulated air drag
enddo
```

Try it ...

First, Save As "`wp12.f95`".

Modify subroutine **`getsounding`** so that after the whole file was read (but before you close the file), you `rewind` the file back to the beginning, and then read and display only the first 5 lines of the file. These are the header lines that don't have sounding numbers in them.

You can code it.   I will follow along later.
Save, compile, debug, run, save.

Loop Control Structures: CYCLE & EXIT

A loop with known starting and ending values and increments, but from which you might want to skip some calculations, or exit the loop early.

```
do index = istart, iend, increment
   blah
   blah
   if (conditional expr) cycle   !skip remaining statements
                                  !but remain inside loop
   blah
   blah
   if (conditional expr) exit    !exit immediately from loop
   blah
   blah
end do
```

Summary

- FORTRAN is a programming language.
- It is designed for scientists and engineers.
- It is multi-paradigm: imperative, procedural, structural, array based, object-oriented, etc.
- It is a compiled language.
- It is used extensively in NWP & other number-crunching jobs in meteorology, physics, & engr.
- You can use any ascii text editor to write the FORTRAN code.

Any Questions so far?